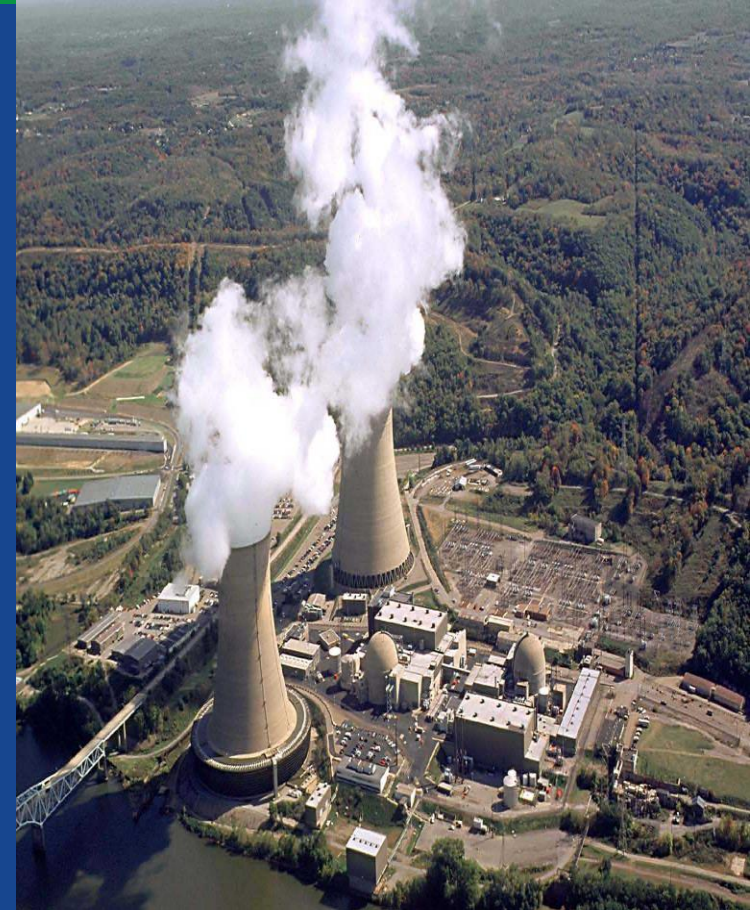


# Steam Generator Alloy 800 Sleeve License Amendment Request

## Pre-submittal Meeting Beaver Valley Unit 2

December 5, 2017



# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Introductions:

- Mark Manoleras, Engineering Director – Beaver Valley
- Tom Lentz, Manager, FENOC Fleet Licensing
- Charles O’Neill, Supervisor, Engineering Programs
- Gary Alberti, Engineering Programs
- Tim Saibena, Engineering Programs
- Greg Kammerdeiner, Fleet Programs Engineer
- William Cullen, Westinghouse
- Damian Testa, Westinghouse
- Rob Taylor, Westinghouse

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Agenda

- Beaver Valley Unit 2 (BV2) Steam Generator Program
- Alloy 800 Nickel Banded Leak Limited Sleeves at BV2
- BV2 Steam Generator Operating and Maintenance Strategy
- Nickel Banded Alloy 800 Sleeve Description
- Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life
- Schedule for FENOC License Amendment Request Submittal to Revise Alloy 800 Sleeve Service Life
- Summary
- Open Discussion

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Beaver Valley Unit 2 (BV2) Steam Generator (SG) Program

- BV Technical Specification 5.5.5, requires that a SG program be established and implemented to ensure SG tube integrity is maintained
- SG tube integrity is maintained by meeting the performance criteria for structural integrity, accident induced leakage, and operational leakage
- The SG program establishes additional provisions for SG tube plugging or repair criteria, SG tube inspections and SG tube repair methods
- Provision for SG Tube Repair Methods:
  - *Westinghouse leak-limiting Alloy 800 sleeves, WCAP-15919-P, Revision 2. An Alloy 800 sleeve shall remain in service for no more than five (5) fuel cycles of operation starting from the outage when the sleeve was first installed.*

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Beaver Valley Unit 2 (BV2) Steam Generator Program

- **1987:** BV2 commenced commercial operation
  - Westinghouse Nuclear Steam Supply System (NSSS) - three loop design
  - Westinghouse Model 51M SGs
    - Alloy 600 low temperature mill annealed tubes
    - Proactive measures implemented prior to commercial operation to mitigate Primary Water Stress Corrosion Cracking (PWSCC ) susceptibility
      - Row 1 & 2 U-bend in situ stress relieving
      - Tubesheet shot peening

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Alloy 800 Nickel Banded Leak Limited Sleeves at BV2

- **2009:** License Amendment 170 approved to permit use of Alloy 800 leak limited sleeves
  - Alloy 800 sleeves approved through the BV2 Spring 2017 outage
    - Five (5) operating cycles from amendment approval
- Technical basis for the five cycle sleeve service limit
  - Prior to installation, the parent tube is inspected at the location of the sleeve joints to ensure the region is free of detectable flaws.
  - Severe degradation in the sleeve joints can be detected during subsequent in-service inspections (ISI).
  - The axial load capability of the sleeve joint is not compromised in the event that severe degradation is present behind the sleeve nickel band region.
  - A limit on the amount of time that the sleeves were to be in service was adopted.

# Steam Generator Alloy 800 Sleeve License Amendment Request

- **Alloy 800 Nickel Banded Leak Limited Sleeves at BV2**
  - **2009 – 2011:** No Alloy 800 leak limited sleeves installed
  - **2012:** 97 Alloy 800 leak limited sleeves were installed
  - **2015:** License Amendment 184 approved for Alloy 800 leak limited sleeves to replace the Spring 2017 sleeve service life limit with a five cycles of operation service life limit
    - Same technical basis as the 2009 Nuclear Regulatory Commission (NRC) Safety Evaluation Report (SER)
  - **2017:** 171 additional Alloy 800 leak limited sleeves installed
    - Currently, 265 sleeves installed

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ BV2 SG Operating and Maintenance Strategy

- In 2017 outage, a full bundle chemical cleaning was performed to proactively manage SG degradation long term
  - 7,086 pounds of material was removed from the SGs
- BV2 is currently operating at less than 100% power due to reduced steam pressure
- Estimate that approximately 70 tubes are required to be returned to service in 2018 to offset reduction in steam pressure



# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ BV2 SG Operating and Maintenance Strategy

- In March 2018, FENOC intends to submit a License Amendment Request to extend the service life of Alloy 800 nickel banded sleeve from five (5) to eight (8) operating cycles
- In addition, FENOC and Westinghouse are working to develop and qualify non-destructive examination (NDE) technique(s) to enhance inspection of the parent tube behind the nickel band
  - May submit a future License Amendment Request to permit unrestricted use of Alloy 800 nickel banded sleeves
- In parallel, FENOC and Westinghouse are working to qualify a non-nickel banded Alloy 800 sleeve
  - May submit a future License Amendment Request to permit use of non-nickel banded Alloy 800 sleeves

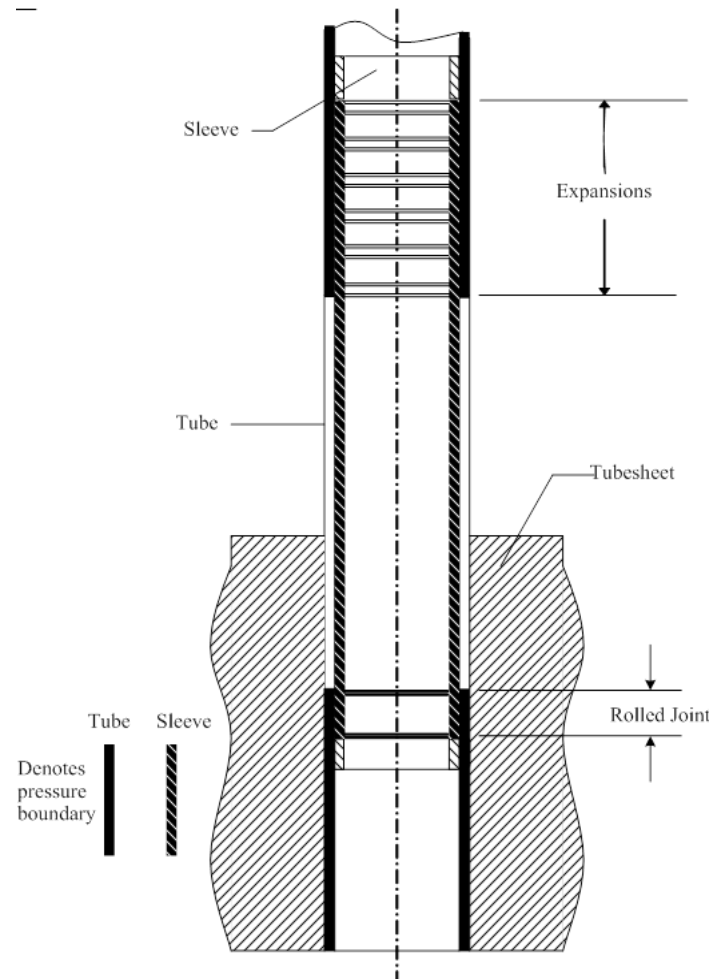
# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ BV2 SG Operating and Maintenance Strategy

- In Fall 2018 outage, FENOC intends to remove plugs to return tubes to service to recover steam pressure
- In Fall 2018 outage, FENOC intends to install additional nickel banded tubesheet sleeves in all candidate locations to minimize number of tubes taken out of service
- In future outages, maintain adequate steam pressure to facilitate 100% power operations through a combination of sleeving, alternate repair criteria (ARC) and plug removal
- Perform analyses to extend the design life of original SGs before March 2027

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Nickel Banded Alloy 800 Sleeve Description



# Steam Generator Alloy 800 Sleeve License Amendment Request

- **Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life**
  - **Topics to Address**
    - Roll expanded joints are robust
    - Prior modified parent tube testing results – even with postulated degradation, joint strength continues to meet the Technical Specification requirement
    - Alloy 800 material corrosion performance update (since 2009)
    - Limited or no potential for degradation of parent tube adjacent to nickel band
    - Summary of Non-NDE Issues
    - Parent tube degradation behind nickel band is detectable with existing eddy current techniques – nickel band noise is not as restrictive as first thought
    - Overall Conclusions

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Roll Expanded Joints are Robust

- Used in numerous power generation and other applications because of their inherent characteristics
- Provide the most load bearing capability and best leakage restriction performance compared to other expansion types
- F\* and L\* ARC address roll expanded joints
  - Typical F\* length ~1 inch at top of tube sheet (TTS)
  - Shorter F\* lengths can be used based on tubesheet elevation; consistent with sleeve roll joint elevation

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Prior Modified Parent Tube Testing Results

#### – Modified Parent Tube (Simulated Cracking) Results

- Notched/separated tube testing with Alloy 800 sleeves
- Performed to confirm postulated parent tube degradation does not reduce axial load capability to < requirement
- Microlok (ML) band increases load capability by a factor of 2

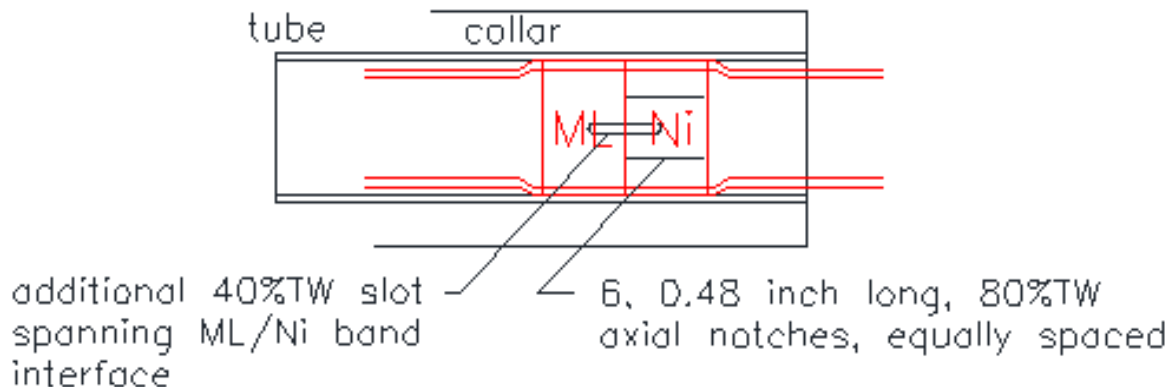
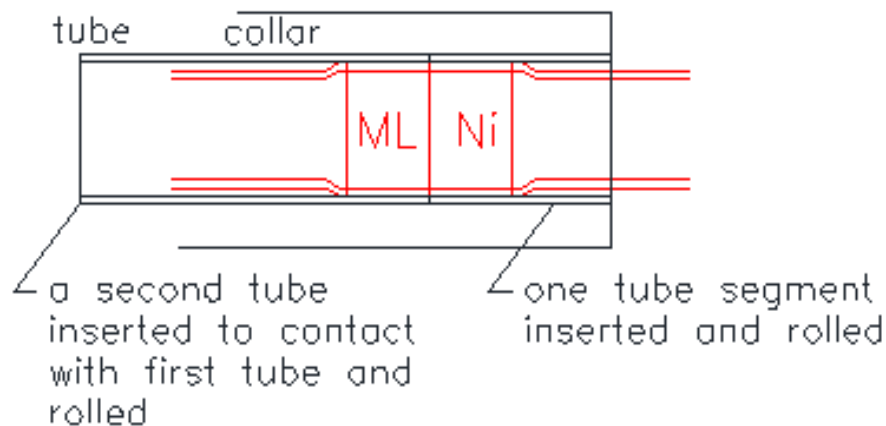
#### – Leakage Testing of Limited Length Alloy 800 Sleeve Joints

- Room temperature and elevated temperature
- Reactor Coolant System (RCS) pressure delivered to ML/nickel band interface
  - Effective joint length of < 0.55 inch
- Leak rates are small for a < 0.55 inch joint length ( $10^{-6}$  gpm)
- Internal pressurization of sleeve not modeled in test; would produce a more leak resistant condition

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Prior Modified Parent Tube Testing Results



# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Alloy 800 Material Corrosion Performance Update

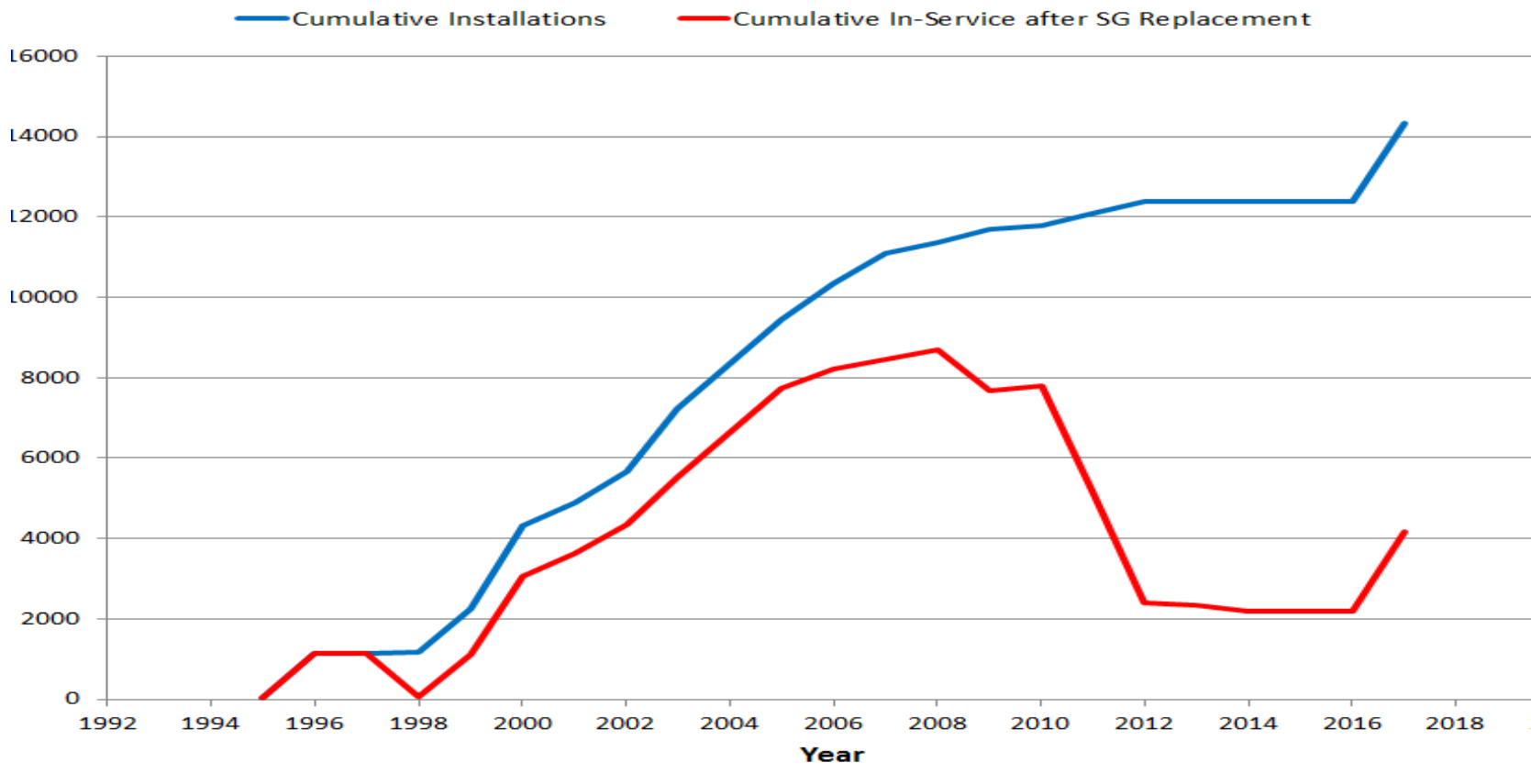
- ISI data from Spanish RSGs with Alloy 800 tubing identified outer diameter (OD) circumferential cracking (~2009 timeframe)
  - Associated with denting at TTS resultant from poor secondary chemistry control
  - Chemical cleaning applied to remove hardened deposits – no stress corrosion cracking (SCC) reports long term
- One German unit reported axial ODSCC in tubesheet (one tube)
  - No additional reports since initial identification



# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### — Alloy 800 Tubesheet Sleeve Installations Worldwide

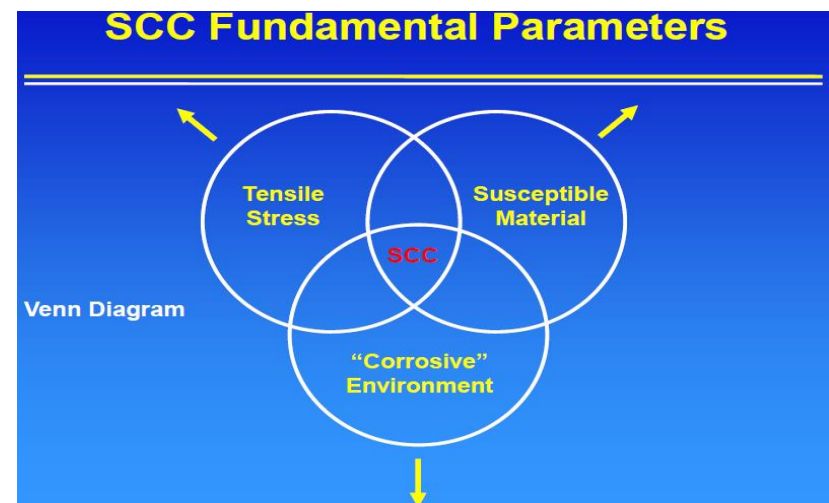


# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Limited or No Potential for Degradation of Parent Tube Adjacent to Nickel Band

- Shot peening greatly improves PWSCC resistance
- BV2 experience (5 PWSCC indications after 19 cycles) is greatly reduced compared to similar non-peened units
- Finite element analysis (FEA) modeling shows parent tube residual stresses are compressive after sleeve installation
- PWSCC potential eliminated



# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### — Summary of Non-NDE Issues

- Parent tube SCC will not reduce lower joint axial load bearing capability to less than the requirement
- Conditions essential for SCC initiation adjacent to nickel band are not present, thus SCC potential is zero
- Effective tube-sleeve joint length of < 0.55 inch used in leakage testing might leak, but leak rate is small ( $10^{-6}$  gpm)

**The ability to detect PWSCC of parent tube adjacent to nickel band has no impact upon the ability of the Alloy 800 sleeve to satisfy the axial load bearing requirement, will not cause primary-to-secondary leakage in excess of the performance criteria and has a limited importance if PWSCC of the parent tube is not expected.**

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Parent Tube Cracking Behind Nickel Band Is Detectable

#### – What NDE data do we have present?

- 50 to 100% through-wall (TW) electrical discharge machining (EDM) notches in parent tube from calibration standard
  - Both adjacent to and not adjacent to nickel band
- One tube with 4 laboratory grown (doped steam) outer diameter cracks
  - Three were 100% TW, one was 84% TW
- Axial EDM notched tubes from tensile testing program with additional slot
- Preliminary probability of detection simulation using industry methods (new)

**The present sample set does not support EPRI Appendix H qualification. However, available data suggests that significant degradation of parent tube will be observed at levels similar to current non-sleeved tube NDE techniques.**

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Parent Tube SCC Behind Nickel Band Is Detectable (Cont'd)

- Testing of EDM notch + slotted tube shows:
  - 40% TW outside diameter slot observed both in and out of nickel band, suggesting penetration of at least 60% into tube, with larger signal amplitudes in nickel band
- Testing of laboratory crack sample shows:
  - All flaws detectable in both 75 and 150 kHz (main analysis frequencies)
  - 100% through-wall flaws detectable in 300 kHz (suggests minimal nickel band influence)
- Noise measurements of BV2 sleeves shows noise is not acute
- Probability of detection (POD) simulation:  
at POD = 0.95, depth ~72% TW

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Nickel Band Alloy 800 Sleeve Service Life

### – Parent Tube PWSCC Detection Capability Summary

- 70 and 130 kHz frequencies penetrate tube to at least 60% TW beyond nickel band/tube interface
- 300 kHz identified inner diameter (ID) initiated degradation
- Multi-frequency review suggests high POD of > 50% through-wall PWSCC
- POD simulation shows degradation depths associated with tensile testing will be detected

**Prior NRC concerns associated with limited number of data are addressed via the POD simulation modeling using EPRI techniques. Additional scrutiny of circa 2008 NDE data suggests nickel band is not “a wall,” but an elevated mean, thus similar detection capabilities are expected for sleeved and unsleeved tubes.**

# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Technical Justification for Alloy 800 Nickel Banded Sleeve Service Life

### – Overall Conclusions

- Roll expanded joints are robust
- Parent tube residual stresses are compressive post sleeve rolling – one of the elements necessary for SCC initiation is eliminated
- Even if parent tube develops SCC adjacent to nickel band
  - Axial load bearing capability satisfies joint requirements
  - Leakage is negligible for limited effective joint lengths
- Existing eddy current detection capabilities will detect PWSCC degradation of lesser depths than used in tensile testing

**When all data is considered, the proposed extension of Alloy 800 sleeve service life will not reduce the levels of assurance of steam generator tube integrity required by Technical Specifications.**

# Steam Generator Alloy 800 Sleeve License Amendment Request

- **Schedule for FENOC License Amendment Request to Revise Alloy 800 Sleeve Service Life**
  - LAR Pre-submittal Meeting – December 2017
  - Submit LAR to NRC – March 2018
  - Request Date for NRC Approval – March 2019
  - LAR implementation – April 2020



# Steam Generator Alloy 800 Sleeve License Amendment Request

## ■ Summary

- Submit a License Amendment Request to extend the use of nickel banded sleeves for three (3) additional operating cycles
- When a NDE technique is qualified to evaluate behind the nickel band, FENOC may submit a future License Amendment Request to allow unlimited use of the installed nickel banded sleeves
- Qualification of a non-nickel banded sleeve when completed will permit unlimited use once approved

BE WHAT *matters*.

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**Open Discussion**